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MACROECONOMIC SCENARIO BUILDING
FOR STRATEGIC NATIONAL DEFENSE PLANNING

by

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A variety of uncertainties make defense planning a difficult task even under the best of circumstances. The more varied threat environment in the post-Cold War era, the high price of replacing aging weapon systems and other uncertainties make contemporary planning even more problematic. There is a clear need for more and better tools to address the uncertain variables in the planning equation.

This study explores such tools. It deals explicitly with two levels of uncertainty. The first level is captured with the method of scenarios (from Peter Schwartz). The second level is the "usual" variability of economic affairs within each scenario. This second level is captured using standard econometric and simulation methods. The benefit of this approach is mainly insights for planners – primarily into the sources of uncertainty and their effects (as opposed to point estimates).

The People's Republic of China (2001-2021) is offered as an illustrative exercise. Within that case, we address uncertainty among three scenarios for China's economic future, as well as sources of variance within those scenarios.

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MACROECONOMIC SCENARIO BUILDING FOR STRATEGIC NATIONAL DEFENSE PLANNING

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ABSTRACT

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I. INTRODUCTION

> National security and economic policy are inextricably linked. To secure its existence in the international system, a state must make strategic choices in both peace and war. To implement a strategy, the state must have access to adequate economic resources. Ultimately it is impossible to separate economic power from political power. Whatever enhances the commercial, financial and industrial power of a state increases the military potential of that state.
>
> Mackubin Owens, *The Political Economy of National Defense*

> "Planning is the replacement of uncertainty with error"
>
> Professor Patrick Parker

A. BACKGROUND

Strategic planning for national defense is an extremely controversial topic about which there are many and vastly different schools of thought and methodologies. Difficulties inherent to defense decision making include uncertainties about the enemy, the economy, technology and future events. Adding to these difficulties is the fact that bringing new weapons systems from concept to operational duty can take well over a decade.[1] As time to operational fielding has increased, the price of weapons systems has grown 5-7% per year. While this inflation brought increased capabilities of the systems, the escalation in an era where spending on national defense has decreased in both actual and real terms, has caused a crises situation for defense planners. The result is that the present US military force simply cannot be recapitalized at a realistic price.

As a result, precise strategic planning is more important than ever. The consequences of inaccurate planning assumptions might be obsolete, expensive, ineffective systems. The implications of failure and the constrained fiscal environment

[1] The initial conceptualization of the Aegis weapons system occurred in 1963 and it was not deployed operationally until 1981

make national defense decision-making one of the most complex and vital tasks that our nation's leaders face.

The US defense planning process has been relatively stable since the early 1960's when the Planning Programming and Budgeting System (PPBS) was instituted. There are multiple points of access to the process from the President, Congress and the Armed Forces in this system. One criticism of the defense procurement system is that the PPBS and the Congressional Budget Process are notoriously shortsighted and partisan. This is despite the 5 to 6 year planning horizon in the Future Years Defense Plan (FYDP). Compounding the situation is that several major stakeholders have conflicting interests including "turf" battles for mission areas amongst the services and "pork" for constituents of politicians.

Whether or not the current system is set up to actually allow strategic thinking far enough in the future to react to emerging trends is debatable. One thing that is certain however is that there needs to be a coherent process that can provide an unbiased focus on strategic planning. Use of the best available qualitative and quantitative management tools should be used to focus on key driving issues. This thesis will attempt to tackle one of the most important and unpredictable factors, which influence the future strategic planning terrain. That issue is the economy.

Economics studies allocation of scarce resources. Planning for national defense is an excellent illustration. At the national level the correct balance between public and private sector spending must be struck so that security is maintained while growth encouraged. This problem is usually resolved with reference to the relative percentage of GDP to be spent on defense. This percentage has lessened in recent years due to the increase of "non-discretionary" spending as a percentage of the total expenditures and growth of the national economy while the threat has diminished.

Given the importance of the economic dimension to planning future defense force structures, a means of evaluating alternate scenarios is necessary. Peter Schwartz is a leading proponent of scenario building methodologies for the public and private sector. His guidance has allowed his clients to gain crucial insight into a variety of emerging situations by examining these scenarios. His general technique is to identify crucial issues and the factors that affect them. Once these factors have been sized up, models can be developed and conceptual thought about the potential outcomes can be fleshed out. (Schwartz, 1991)

Economic forecasting is inherently inaccurate. While complex models have been proposed by some extremely bright minds, no one has been consistently accurate in their predictions. An apropos ancient Arab proverb states, “He who predicts the future lies even if he tells the truth.” Managers and planners who use standard economic forecasts as fact are missing the point. Correct focus is to identify the factors that are part of growth and productivity changes, and to evaluate them in the context of alternate scenarios. Armed with these insights, the planner is then prepared for the eventuality that events do not unfold as expected.

This thesis is based on that thought. Economists have developed several models of economic growth. These models usually contain two basic categories of variables. The first is the growth rate of inputs and the second is rate of growth in output relative to growth of the inputs. The resultant is a point estimate that is highly sensitive to individual variable shifts. A crux of this research is to examine the uncertainties of these variables. That is, what happens to growth if the factors change in ways other than standard models assume?

Within scenarios, Monte Carlo simulation is a technique that has become quite accessible to business leaders for evaluation of potential risk with alternative policies. The technique uses random number generators and statistical distributions that can be derived from management assessments of a situation or from historical data. The outcome from the model is then a distribution of possible outcomes. The policy maker can evaluate risks by potential impact and relative probability of occurrence and make policy choices accordingly.

This thesis will propose a comprehensive planning methodology that will incorporate elements of scenario development, risk management, econometric modeling and Monte Carlo Simulation to capture insights about future GDP growth and the implications for defense planners. A potential rival nation will be utilized to demonstrate the method with real world data and alternative scenarios.

B. PURPOSE

The purpose of this research is to examine the effects of uncertainty in economic forecasting as a key variable in national defense decision-making. The relative strength of our own economy and that of potential enemies determines the ability of potential competitor nations to field an effective and modern armed force. Given the importance of this factor and the large degree of uncertainty surrounding economic forecasts, a sound methodology must be developed which considers a broad range of potential futures scenarios and quantifies the risks of making decisions within these scenarios. This thesis will seek to develop such a model and illustrate its use by applying it to a real world nation.

C. SCOPE AND METHODOLOGY

A review some of the important concepts of risk management, modeling and stochastic simulation, macroeconomic production theory and econometric modeling will be conducted. Suggestions for a comprehensive tool to evaluate alternative scenarios of future economies using a combination of several methodologies will be presented.

The model that will be introduced will be simple enough to use in a standard spreadsheet with a Monte Carlo Simulation plug in (such as Crystal Ball) yet robust enough to provide detailed insight into the decisions to be made. A Bayesian analysis will also be suggested for calibrating the model as new observations arise.

D. ORGANIZATION OF STUDY

The study will be organized by first introducing the key concepts in the early chapters and then presenting a cohesive model in detail. After this model is adequately articulated it will be applied to the Peoples Republic of China (PRC) using actual historical data and introducing assumptions in the form of data to model other scenarios. Insights that result from this analysis will be collected and suggestions for future research will be presented in the conclusion.

II. RISK MANAGEMENT AND STRATEGIC PLANNING FOR NATIONAL DEFENSE

> Managing risk is a central element of the defense strategy. It involves balancing the demands of the present against preparations for the future consistent with the strategies priorities… over the past 60 years, the United states has spent an average of 8 percent on the Gross Domestic Product on defense; in 2001, 2.9% of the GDP was spent on defense. The tendency to reduce spending in periods with no clear or well-defined threat has the potential effect of creating risks by avoiding or delaying investment in the force.
>
> Quadrennial Defense Review Report. 2001

A. REVIEW OF RISK MANAGEMENT PROCESSES

Uncertainty about a situation can be considered risk. Risk in its most basic definition is "the possibility of suffering harm or loss; danger." (www.dictionary.com) The implications of this definition for national defense are obvious. The problem for national defense decision makers is to manage the array of possible risks, and to craft a flexible and responsive force.

The continuum of risks that affect military establishments runs the gambit from extreme catastrophic events such as an attack by weapons of mass destruction to relatively minor peacekeeping incidents that characterized the security environment of the 1990's. Relative probabilities of these events and the associated costs must be assessed to determine where resources should be allocated to minimize expected harm. While risk is inherent in any defense problem, an honest effort to assess costs and benefits of alternative courses of action is important to planning for the future.

Risk management is a technique that organizations use to evaluate vulnerabilities and think about outcomes. This technique implemented in many variants is a key component of strategic planning. Risk assessment takes place at several levels of the national defense resource allocation process. Risk management is factored into the PPBS process, as requirements are generated in the planning phase.

B. RISK MANAGEMENT IN CURRENT DOD PLANNING PROCESSES

The risk management approach of the DOD resource allocation process differs from other discretionary budgetary areas where an incremental approach is usually taken. Given the crucial nature of defense there is generally more oversight to defense decisions throughout the process than on other programs where funding and direction escape review on a yearly basis. Cuts in funding to defense increase the risk assumed. This risk must be acceptable to the overall guidance from the executive branch and considered carefully.

The threat and vision for defense is defined and articulated through the planning stage of the PPBS. Since no (formal) fiscal constraint exists until SECDEF's Defense Planning Guidance (DPG) is released. The Programming phase of the process defines, schedules and allocates resources to counter the proposed threat. Finally, the budgeting phase puts dollars to the defense priorities after several rounds of debate.

Documents such as the Quadrennial Defense Review (QDR) and Joint Vision 2020, and the National Military Strategy are also examples of formalized strategic planning. These documents look to the future and analyze trends and possible risks. From these visions, guidance is provided for planning forces and establishing doctrine to counter anticipated threats. The Program Objectives Memorandum (POM) is the primary programming document that each service generates. It represents the six-year plan for allocating resources and is largely influenced by the DPG. The Congressional process balances these DOD strategic plans where many of the same issues are assessed at the Authorization and Appropriations committees.

It is clear that the current military planning system does have mechanisms that assess risk and compel strategic planning. One critical disconnect however is the planning horizon versus the time it takes to operationally field a weapons system. While there are mechanisms of longer range planning in such places as the Office of Net Assessment, the outermost reach of the formal process is the 6-year focus of the POM. What are the potential risks that are exposed in the meantime? Is there a way to minimize or at least plan for risks beyond this timeframe? Peter Schwartz's scenario based methodologies are designed to answer these questions.

C. INTRODUCTION OF SCENARIO BASED STRATEGIC PLANNING

> Scenarios are alternative environments in which today's decisions can be played out. They are not predictions. Nor are they strategies. Instead they are descriptions of different futures specifically designed to highlight the risks and opportunities involved in specific strategic issues
>
> (Ogilvy, Schwartz p.79)

Scenario building and evaluation is a powerful way to think critically about the future. Author and consultant Peter Schwartz describes this process in his work, *The Art of the Long View.* His contention is that "scenarios are not predictions" but rather outcomes that reflect alternative driving forces. He describes the utility of this technique in the following way: "scenarios are . . . the most powerful vehicles . . . for challenging our 'mental models' about the world and lifting the 'blinders' that limit our creativity and resourcefulness." (Schwartz, 1991 p. xv)

Schwartz argues that scenarios should be used as informal simulations to facilitate thinking more concretely and accurately about what might come next. Hopefully these give courses of action that are good regardless of which future actually occurs. Such scenarios are like projected script plots for a movie, and help develop "memories of the future". (Schwartz, 1991 p. 32)

Schwartz then describes how scenarios become strategies. This evolves from the use of knowledge and intuition of the external environment, combined with the internal vision, culture, and competencies of the organization itself. He gives reasons for examining five categories of driving forces of the future, which include society, technology, economics, politics, and the natural environment. Within these areas his general approach is to examine one scenario that is better than the current direction, one worse, and one different. Moreover, he suggests the following eight steps for developing scenarios that are helpful for strategic planners:

1. Identify focal issue or decision
2. Identify key forces in the local environment
3. Identify driving forces
4. Rank these by importance and uncertainty
5. Select scenario logics
6. Flesh out the scenarios
7. Determine implications
8. Select leading indicators and signposts

These steps lead the planner down a road where critical insights can be gained, context developed and mind frames developed and prepared for action. (Schwartz, 1991)

This approach is especially valuable to national defense planning. The nature of assessing national security threats even in the short run since the end of the cold war is notoriously difficult. Uncertainty, according to Schwartz is the primary driver for evaluating these scenarios. The events that have unfolded since the terrorist attacks of September 11, 2001 provide an illustration. Since the fall of the Soviet Union, US defense planners have argued vehemently about the direction and architecture of the armed forces. Many would argue that the lack of certainty of potential foes has resulted in a situation where the armed forces continue to build to a cold war style two-MRC (major regional conflict) style war. Pundits have long decried peacetime military leaders of having a "last war" mentality. With better insight provided by this detailed scenario building methodology, we might have lessened vulnerabilities exploited by the recent terrorist attacks.

III. RISK ANALYSIS USING SPREADSHEET MODELING AND MONTE CARLO SIMULATION

A. INTRODUCTION

Modern spreadsheets such as Microsoft Excel have the capacity to provide accurate record keeping, data collection and dissemination. They also have the ability to model situations that are important to decision makers with sufficient fidelity to be useful. These models reflect the postulated mathematical relationships between decision variables, and can produce results that can yield critical insights.

B. SPREADSHEET SCENARIO MODELING

Decision makers of necessity rely heavily on spreadsheet models to evaluate a variety of potential scenarios. The models are populated with known variables and their mathematical relationships. For each variable there is a degree of uncertainty. Traditionally, spreadsheet analysis has tried to capture this uncertainty in one of three ways: point estimates, range estimates, and what-if scenarios.

Point estimates utilize most likely values (mode) for uncertain variables. While these estimates are simple and commonly used, their result can be misleading. For example, crossing a river with an average depth of three feet is a tenuous proposition. Similarly, if it takes you an average of 25 minutes to get to the airport, leaving 25 minutes before your flight takes off will find you missing your plane half the time.

Range estimates typically calculate three scenarios: the best case, the worst case, and the most likely case. These types of estimates show a range of outcomes, but not the probability of any of these outcomes.

What-if scenarios are usually based on the range estimates, and calculate as many scenarios as are deemed appropriate. This scenario-driven approach is somewhat similar to the Schwartz methodology. What is the worst case? What is the best case? Calculating these for each variable becomes a time consuming task but still doesn't provide the probability of achieving any different outcome.

C. SPREADSHEET RISK ANALYSIS

Risk analysis can be performed in several ways, but one method involves building a spreadsheet model. A good spreadsheet model can be very helpful in identifying where risk might be, since cells with formulas and cell references identify causal relationships among variables. One of the drawbacks of conventional spreadsheet models is that each cell can take only one value at a time. This limitation prevents a direct investigation of a range of values for a cell. Calculating a range by replacing uncertain values several times to see the effect of various values. Calculating more realistic "what-if" scenarios is the same, except it requires changing the spreadsheet even more. Furthermore, the scenario results have to be tracked somewhere. Simulation with a spreadsheet allows uncertain variables to be modeled by defining a cell with a range or a set of values.

D. MONTE CARLO SIMULATION

The word “simulation” refers to any means used to imitate a real-life system, especially when other analyses are too complex or too difficult to reproduce analytically. Without the aid of simulation, a spreadsheet model will reveal only a point estimate, generally the most likely or average outcome. Spreadsheet risk analysis uses both a spreadsheet model and simulation to automatically analyze the effect of varying inputs on outputs of the modeled system.

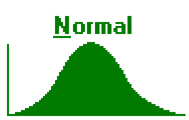
One type of spreadsheet simulation is “Monte Carlo” simulation, which randomly generates values for uncertain variables over and over to explore a model’s consquences. The method was named for Monte Carlo, Monaco, where the primary attractions are casinos containing games of chance such as roulette wheels, dice, and slot machines. Mathematician John von Neumann is credited with its development in conjunction with the Manhattan Project in World War II. With the advent of affordable and rapid computing, the technique has been borrowed and refined for a variety of applications from the engineering and science fields to business applications. In addition to being able to simulate inventory management and queuing theory it can also be applied to economic forecasting.

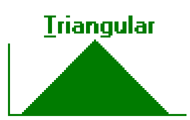
E. HOW MONTE CARLO SIMULATION WORKS

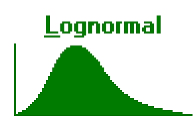
The random behavior in games of chance is similar to how Monte Carlo simulation selects variable values at random to simulate a model. When a die is rolled, only a 1, 2, 3, 4, 5, or 6 will come up, but the result at any roll is unknown. It's the same with the variables that have a known range of values but an uncertain value for any particular time or event (e.g. interest rates, skilled-labor availability, capital costs, inventory, etc.).

In a spreadsheet model which uses Monte Carlo Simulation, a probability distribution is defined for each uncertain variable (one that has a range of possible values). This information can be based on historical data, known statistical distributions (with such factors as means and standard deviations), or other information provided by those familiar with the system.

The type of distribution selected is based on the conditions surrounding variable. Typical distribution types include:





and


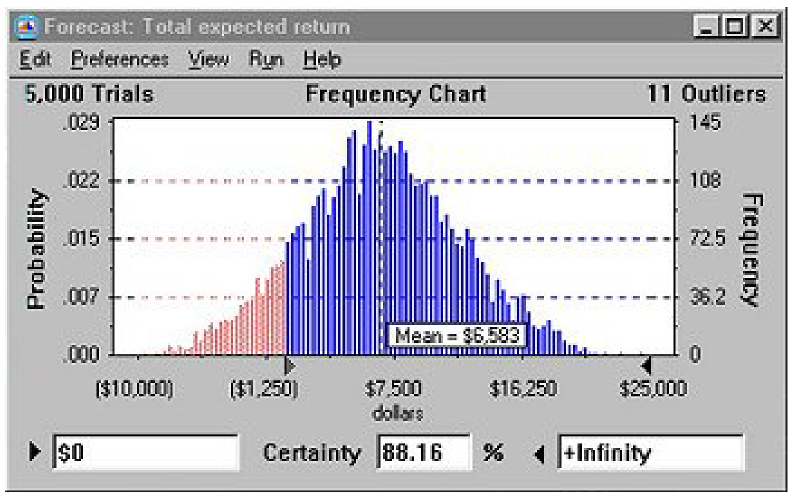
.

(From: Decisioneering Software, 2001)

While it is possible to add this sort of function to a spreadsheet, entering the equation for the respective distribution would be time consuming and difficult to populate with data. Plug-in software such as Crystal Ball for Microsoft Excel is readily available where these equations are automatically calculated. Crystal Ball can also fit a distribution to any historical data available.

A simulation calculates multiple outcomes of a model by repeatedly sampling values from the probability distributions for the uncertain variables and using those values for the cell. Crystal Ball simulations can consist of as many trials as desired, limited only by the complexity of the model and the computing power available.

During a single trial, the software randomly selects a value from the defined possibilities (the range and shape of the distribution) for each uncertain variable and then recalculates the spreadsheet for the final outcome or forecast. This forecast cell is defined by the modeler and is generally the outcome that is being studied. After each iteration of the model the software records the value and plugs it in to an outcome distribution. During the simulation a graphical histogram of the results, referred to as a Frequency Chart, is developed for each forecast. As the number of iterations increases, the forecasts stabilize toward a smooth frequency distribution. After the preset number of trials is complete, the statistics of the results (such as the mean forecast value) and the likelihood of any given outcome are available for viewing and analysis. The example below is a forecast for total expected return.



(From: Decisioneering Software, 2001)

F. WHAT IS CERTAINTY?

Certainty is the chance that a particular forecast value would fall within a specified range. For example, in the Crystal Ball chart above, the certainty of breaking even (results better than $0) is available by entering $ 0 amount as the lower limit. Of the 5000 trials that were run, 4408 (or 88.16%) of those had a positive total expected return, so certainty or confidence of breaking even in this case is 88.16%. Therefore, the forecast results not only show different results for each forecast, but also the probability of any value. This feature allows a complete evaluation of a myriad of “what-if” situation. (Decisioneering Software, 2001)

Other features of Crystal Ball allow the analyst to examine different facets of the model. The Sensitivity Chart allows analysis of the contribution of the assumptions (the uncertain variables) to a forecast, showing which assumptions have the greatest impact on that forecast, or what factor is most responsible for the uncertainty of outcomes. Sensitivity analysis can provide insight on which decision variables that matter most.

G. SUMMARY

While risks must be taken to succeed in any venture, including national defense, blind unassessed risks often lead to costly errors. The nation is making "you bet your country" decisions when planning an armed force. This technique is one more analytic tool to aid defense decision makers by helping assess risks and risk reduction measures. The sensitivity analysis feature provides the added benefit of allowing the policy maker to focus on variables they can control to best influence the final results. Each time a simulation is performed, a richer understanding of the inherent risks is obtained. This tool fits well within the Schwartz method of scenario building and gives critical insights about the relative probabilities of alternate outcomes within scenarios.

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IV. MACROECONOMIC THEORY AND FORECASTING

A. INTRODUCTION

> "Life is a trap for logicians because it is almost but not quite reasonable." It looks just a little more mathematical and regular than it is. Its exactitude is obvious but its inexactitude is hidden; its wildness lies in wait."
>
> G.K. Chesterton (English writer)

> "It is dangerous to make forecasts, especially about the future."
>
> Yogi Berra

Whether or not these statements are understood by those who design complex models for predicting the future of the economy is questionable. There is ample evidence that some see these models as a science rather than the art that it is. An enormous amount of time and resources of some the most successful organizations in the country have gone into quantitative modeling of future trends and outcomes. Why is this so if the future cannot be predicted with confidence?

The answer lies in the insights provided by the process. Schwartz would say mental models are improved. According to his theory of scenario building, several "futures" should be examined, including the most likely case, an extremely bad case and an optimistic case. Using this framework in tandem with modern modeling and simulation methods can arm decision makers with the tools to rapidly evaluate a broad range of possibilities. They can also be changed to reflect current parameters such as technology, demographics and geopolitics.

Additionally, simulation methods allow attachment of statistical likelihoods to scenario forecasts and associated conditional probabilities. The utility of this approach is that risk management techniques introduced earlier can be utilized to assess risk. A defense economic example might be that there is a 1 in 10 chance China's GDP could grow to 11 trillion dollars by 2005. By seeing this figure plus a relative likelihood of alternative possibilities, more informed decisions are possible.

The correct perspective must be maintained throughout this process however. Reliance on modeling outcomes as predictors rather than insight producers can be disastrous. The rapid destruction of the hedge fund Long Term Capital Management in the fall of 1998 is a case in point. This fund traded extensively in derivatives and arbitrage with use of heavy leverage. Their use of computer models developed by the crème of academia, including Nobel Prize winners, relied on historical data and assumptions. When Russian debt default triggered the Asian financial crises of the 1997, the historical norms of arbitrage trading and bond yields broke down. In five weeks the Long Term Capital's portfolio imploded under the weight of its leverage. Massive margin calls and elimination of credit with market makers led to losses so massive that the US Federal Reserve felt obligated to arrange a bailout to protect the rest of the economy. (Lowenstein, 2000).

B. MACROECONOMIC PRODUCTION THEORY

Economic forecasting has been around since the dawn of the mercantile system. Recent advances in computing power and simulation theory have armed economists with new tools to test their theories. This section will examine some of the methods and theory used to predict growth.

These theories attempt to mathematically model growth of an economy by quantifying two basic categories. The first is the growth factor of inputs and the second is growth in output relative to the growth of the inputs. The two main factor inputs are capital (K) and Labor (K). A general form of the equation relates GDP (Q) to an autonomous growth factor (A) (or total factor productivity growth) the geometrically weighted average of labor and capital in following fashion:

$$Q = A\,K^{\alpha}\,L^{(1-\alpha)}$$

This is the basic form of a production equation and provides a baseline on which more sophisticated modeling is based. (Gordon, 1990, p. 362)

C. REVIEW OF MACROECONOMIC MODELING FOR NATIONAL SECURITY DECISION MAKING

DOD uses the RAND Corporation extensively as a consultant on a variety of issues surrounding national defense. A notable series of RAND reports focus on the economy and demographic trends as key drivers of the emerging national security environment in the next 15 to 20 years. The most recent example of this series is *Asian Economic Trends and Their Security Implications* and uses their technique as a framework from which to gain insights about possible futures in the Pacific Rim. Since they are generally considered as the paragon of this area of economic research, a review of its basic methodology is useful.

The basic method has four major steps beginning with the estimation of GDP's for various nations based on the Cobb Douglas Production Function. This estimate is combined with demographic predictions to derive GDP per capita. Military spending as a proportion of GDP is then estimated based on historical data. The final and most tedious step involves estimating military capital. This is calculated by estimating the spent on procurement and adding this to the depreciated stockpile of existing equipment.

This methodology is encapsulated the following mathematical relationships.

Equation (1): $$Q = e^{\tau t} L^{\alpha} K^{(1-\alpha)}$$

(Cobb Douglass Production Function)

Where: Q = Real GDP

τ = technological rate of change (total factor productivity)

t = time in years

α = labor share in GDP

L = labor input each year

K = capital input each year

Equation (2): $MS_t = \gamma\, GDP$

MS_t = military spending in year t

γ = proportion of GDP devoted to procurement of equipment and construction

Equation (3): $MK_t = \pi\, MS_t + MK_{t-1}\,(1-\delta)$

MK_t = military capital stock in year t

π = proportion of GDP devoted to military spending

δ = depreciation of military capital

Equation (1) can also be expressed by taking logarithmic derivatives of the variables with respect to time.

Equation (4): $Q^{\bullet}/Q = \tau + \alpha\,(L^{\bullet}/L) + (1-\alpha)(K^{\bullet}/K)$

This form is useful for the model and stipulates that the rate of growth in GDP is equal to the annual growth of total factor productivity (technology progress- τ) plus the rate of growth in employment multiplied by the share of labor income in GDP (α), plus the rate of growth in the capital stock multiplied by the share of capital income in GDP ($1-\alpha$). This output rate of growth can be applied to actual GDP data to model future trends. The rate of growth of total factor productivity can be estimated from other known values in Equation (4). The labor and capital income shares in the study are based on historical data and educated judgments. RAND draws their data from a wide array of unclassified sources for individual nations including their published statistical yearbooks.

For comparison between nations, estimates of gross domestic product (GDP) estimates are based on purchasing power parity (PPP) calculations rather than on conversions at currency exchange rates. PPP dollar estimates are calculated by applying standardized international dollar prices to a country's output of goods and services and are considered the best measure for international comparisons of GDP. This calibration factor remained constant throughout the 20-year period of study and was derived from the CIA World Factbook (*The CIA World Factbook*, http://www.cia.gov/cia/publications/factbook/fbhome.html) for the year 2000. It should be noted that PPP is an estimate that is subject to error and variance itself but this figure is used as a best guess constant since it is easily assessable and can be compared to other nations easily.[2] The study estimated the parameters using a variety of methods including historical data and educated forecasts.

Alternative scenarios can be proposed by manipulating these key parameters to fit the scenario. For example alternative total factor productivity growth scenarios could model potential increases in technological capability or infrastructure. The effects of these differing numbers would affect the ultimate GDP forecast.

D. SUMMARY

The RAND method seeks to meld traditional economic growth theory with quantitative and qualitative assumptions about the socio-economic environments of the respective countries into an integrated educated view of a possible future. This technique bears some similarity to the Schwartz method of scenario building and presents national defense planners with a set of assumptions to frame future decisions. RAND acknowledges the uncertain nature of the results but there is no attempt to quantity it in any way.

[2] For the purpose of this study all dollar values will be in PPP for the reasons discussed on this page.

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V. PROPOSED METHOD

A. INTRODUCTION

This thesis has discussed a number of techniques pertaining to developing a more complete picture of the strategic environment and its risks. In particular the study focuses on the economy and the variables that drive it. Its ultimate aim is developing ways to improve the mental models of defense planners. They can then make more informed decisions about allocating resources in the uncertain environment in which they must operate. This chapter will propose a methodology to properly assess the driving forces in the strategic situation and address the risks in the assumptions made. It will extend the methodology developed by the RAND report to include a consideration of uncertainty to provide a measure of the distribution of outcomes within a scenario.

B. ALTERNATIVE ECONOMIC SCENARIOS

Peter Schwartz's scenario building methodology proposes that a variety of scenarios be developed on the basis of key issues. They should then be and fleshed out with the existing body of knowledge on the subject. This thesis focuses on the economy, in which there are a host of driving factors and trends that must be considered.

While there is a continuum of possible outcomes that can occur, the best way to develop the crucial insights needed is to look at a discrete set of circumstances. In particular these circumstances should be a status quo, optimistic and pessimistic scenarios. Each of these stories should be based on real world driving forces. Examples of the key forces, which could be adjusted to reflect a scenario, might be the degree of technological growth, and of labor and capital employment. Before the scenarios can be developed a great deal of research must be conducted to identify the key variables. Once identified, they should be used to specify and define the scenario.

C. ECONOMETRIC FORECASTING WITH SIMULATION

The first step in developing an econometric model is to capture the behavior of the GDP and defense budgets in a mathematical format. As previously discussed, the Cobb Douglas Production Function is an adequate basis to model GDP over time. The logarithmic derivative of this function yields a rate of growth of GDP and can be applied to recent GDP and purchasing power parity data to produce comparable GDP numbers. The next step is to estimate a percentage of GDP spent on defense for the country. This information can be derived from historical sources or defined by specific scenario events. Once this data is programmed into a spreadsheet, a large amount of output data can be produced. One useful output for defense planner is a time series plot of both GDP and the estimated defense budget.

The variables in this model can be manipulated to fit the assumptions of the various scenarios. Major changes in total factor productivity growth or labor and capital share of GDP can reflect major changes in the economy, culture or military policy. These variables should then be carefully considered within the realm of historical experience and educated guessing based on the driving trends that have been previously identified.

Once the respective scenarios have been modeled in the point estimate realm, the next step is to start the simulation process with the aim of identifying effects of key uncertainties. Definition of the statistical distributions for each variable should be conducted after carefully evaluating historical performance and scenario assumptions. This requires a mixture of research and hypothesis to define these them. For the status quo scenario the best method is to simply use historical economic means and standard deviations of the variable in question. If there is an available mean and standard deviation then a normal distribution should be used for the cell. If there is no notable trend in the data towards a mean then a uniform distribution should be used. This option allows a spread of values to be evaluated with equal statistical likelihoods in the variables. While these two distributions should suffice for most analyses, there are some other functions that might be useful. Crystal Ball allows the design of a custom distribution based on historical data. This is an interesting function but is not continuous and may be too tightly defined for the uncertainty of an economic model. Perhaps a better technique to use with actual data is to employ a some software program to process the data and propose the best-fit statistical distribution. Finally, a simple method that may be useful is the triangular distribution. This function allows the planner to assign a most likely, optimistic and pessimistic range for the variable.

Once the model is built and tested, and the variables are defined, it is time to carry out the simulation. The actual forecast variable and cell needs to be defined to begin the process. Since the focus of this thesis is on long range economic planning, the year 2021 will be the forecast date. It is important to note that once the model is built it is relatively easy to change the forecast year and also the assumptions. This gives the planner some flexibility to consider alternative approaches for varying time frames.

The simulation should be run with a sufficient number of iterations so that the forecast distribution looks relatively smooth. For the purposes of this model, 2000 iterations seem to be adequate. Once the simulation is complete there needs to be an analysis of the results. Crystal Ball provides ample options for report generation. Some useful formats are the summary statistics and the graphical frequency chart. The planner can readily ascertain the relative probabilities of an economic result given the scenario from these reports. These outputs can be compared between competing nations under a common scenario and conclusions drawn about military capabilities in future years. The results and their uncertainties could easily be plotted on the same chart. An example of an insight that could be drawn from such an analysis is: when will one country's GDP (or defense spending) overtake another's based on a set of assumptions. This analysis might help define a long-term force structure based on relative economic strengths.

D. BAYESIAN PROBABILITY ANALYSIS

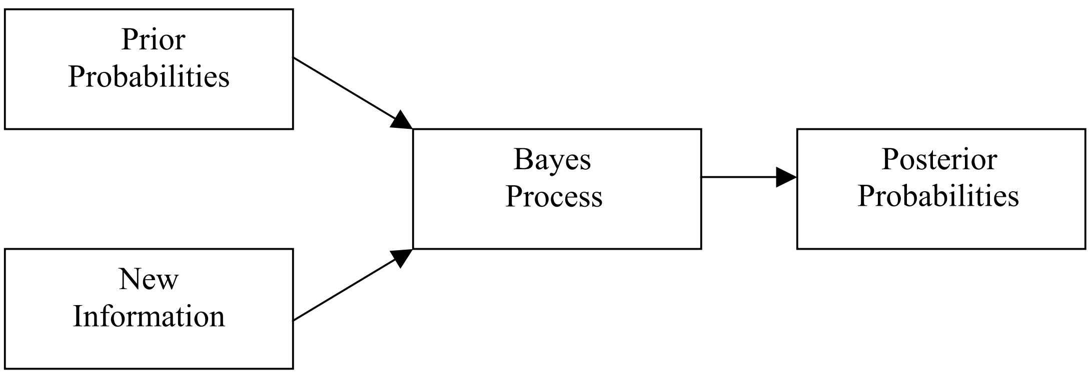
Presbyterian minister Thomas Bayes introduced his theory of conditional probabilities in the 18th century. The general form of Bayes law gives a conditional probability of an event A given another event B as follows:

$$P(A|B) = \frac{P(A|B)}{P(B)}$$

This formula can be mathematically manipulated into the following form that can be used to update prior probability distributions.

$$P(A|B) = \frac{P(B|A)\,P(A)}{P(B|A)\,P(A) + P(B|A^*)\,P(A^*)} \quad \text{(Where A* is the complement of A)}$$

This technique called Bayesian analysis uses actual data and observations to produce a posterior probability distribution. This feature makes it an excellent tool to refine econometric models. The posterior distribution that is calculated then acts as the prior distribution for the next iteration of a model. This process is graphically depicted as follows:



For the purposes of this study, Bayesian Analysis can be used to evaluate and tune the models to reflect real world happenings. Actual economic data could be compared to the scenarios so that a relative probability of which set of assumptions a planner is operating under can be evaluated.

E. SUMMARY

The methodology presented in this chapter is designed to meld a variety of techniques and methodologies developed by economists, business people and defense planners to predicting a set of future results and determine the relative likelihood of these forecasts. The Cobb Douglas production function was proposed to underpin the model of GDP for nations of interest. A variety of research methods to obtain valid estimates for the variables in this equation were discussed. Monte Carlo simulation methods are also proposed to account for uncertainty in the model. Finally, Bayesian posterior probability analysis was introduced as a tool for refining a models assumptions and providing insights to the planner as to which scenario is actually modeling the actual economic behavior the best.

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VI. AN ANALYSIS OF THE PEOPLES REPUBLIC OF CHINA USING THE PROPOSED MODEL

> Although the United States will not face a peer competitor in the near future, the potential exists for regional powers to develop sufficient capabilities to threaten stability in regions critical to U.S. interests. In particular, Asia is gradually emerging as a region susceptible to large-scale military competition. Along a broad arc of instability that stretches from the Middle East to Northeast Asia, the region contains a volatile mix of rising and declining regional powers.
>
> Quadrennial Defense Review Report. 2001

A. INTRODUCTION

The previous chapter presented a methodology designed to study alternative scenarios of economic growth and defense spending with the aim of harvesting insights for military planners. To illustrate this methodology the People's Republic of China will be discussed. This nation was chosen because of its recent surge in economic growth and military might and also because of its growing roll as a regional hegemon in the Pacific Rim. Before the scenarios for the future can be introduced a brief review of China's economic terrain is useful.

B. CHINA'S ECONOMIC KEY ISSUES

China currently has the second largest economy in the world in terms of purchasing power parity behind the US. Since 1978, the country's leadership has begun a shift away from a stagnant Soviet-style economy to a more market-oriented system. The system is still highly controlled by the Communist leadership but there has been a notable trend towards empowering local officials and plant managers. The results of this reform have lead to a quadrupling of GDP since 1978. With an estimated 1.2 billion of population their GDP per capita figure is \$3600 (PPP) in the year 2000. This is dwarfed by the US figure that was \$36,200 in the same year. This indicates that their system is still inefficient and that there is likely great potential for future growth if the labor and capital pool is better utilized (*The CIA World Factbook*, http://www.cia.gov/cia/publications/factbook/fbhome.html).

Much of the literature on the PRC identifies some keytrends that will likely affect their economy. One of those issues is Western influence on the nation. The reintegration of Hong Kong is cited as a major source of this influence as the prosperous province asserts itself as an important driver of the nation's economy. The prospect of a peaceful reunification of Taiwan under a "one-China" umbrella is an event that might accelerate this process. The rapidly expanding use of the Internet and wireless communications has provided a channel to the outside world unprecedented in the history of China. If this trend accelerates, then the entire culture and fabric of the nation and the economy could be profoundly affected.

The demography of China is of course extremely important to the future economic growth prospects of the nation. The sheer weight of one fifth of the world's population presents both burden and promise for the nation. The "one child policy" the nation has been pursuing for the last couple of decades might become a problem if populations begin to become unsustainable as the ratio of males to females increases. (Oglivy, Schwartz, 2000, p. 42) Being able to efficiently channel the labor potential of the populace is a key concern for Chinese economic leaders. With increased communications, potential different demographic groups could possibly unite and become powerful entities in nation's affairs.

Another issue that has surfaced lately is the governments struggle to collect revenues due from provinces businesses and individuals. The pool of resources available to the government will dwindle as a percentage of GDP if this problem is not mitigated significantly. (*The CIA World Factbook*, http://www.cia.gov/cia/publications/factbook/fbhome.html) Availability of energy is another problem that China's economic planners face in the near term. Without an adequate domestic supply of clean-burning coal and petroleum, the nation is faced with a major obstacle in transitioning to a competitive modern economy. A related problem is deterioration of the environment, notably air pollution, soil erosion and a reduction in the water table. While by no means exhaustive, these are the key drivers used in the scenario building exercise below.

C. ALTERNATIVE SCENARIOS

Development of scenarios about China's future has been conducted by a variety of sources besides the RAND study. The Office of Net Assessment, numerous academic institutions and the intelligence community have all conducted such exercises. These respective studies have addressed numerous issues including those key drivers identified above. This thesis will focused on three scenarios. The first represents continued growth "status quo" of the Chinese economy. The next scenario is an interrupted or suspended growth case as the nation struggles with cultural upheaval driven by some of the key socio-political problems previously identified. The final, and most optimistic, scenario is accelerated growth where the efficiency of the labor and capital begins to catch up with levels found in the most advanced nations.

D. CONTINUED GROWTH SCENARIO

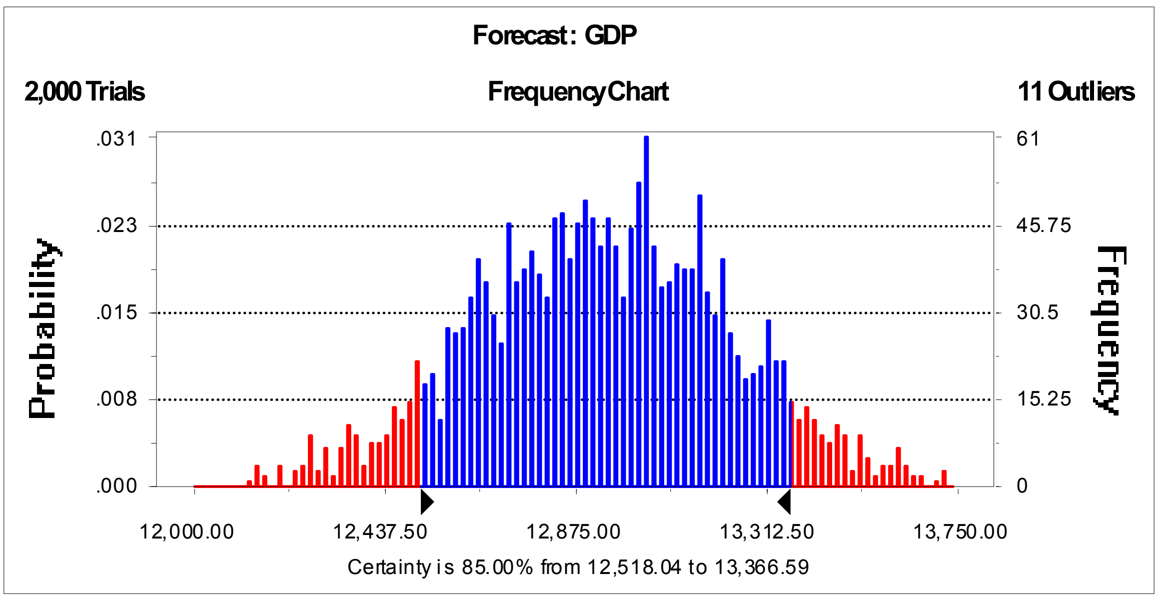
The continued growth scenario is the status quo case. It assumes no major events disrupt the current course that has been set for the economy. This is the best scenario to start from in order to understand potential variances in the outcomes of other scenarios. It will rely on historical data for the variables and will provide a most likely estimate for the future as a baseline. Through the use of simulation, a confidence limit around the forecasts will also be established.

The economic data set used borrows heavily from the RAND Corporation work featuring a similar scenario and point estimates. (Wolfe, 2000) There was no shift of the parameters and their distributions throughout the 20-year epoch in order to keep the context intact. Cyclical variations are accounted for only in the distributions of the respective variables. The GDP growth rates are also lower than that of recent years, which reflects a general slowdown of the world economy in the past year (2001).

The following parameters were used to populate the model to represent the scenario:

τ – total factor productivity growth	Uniform DISTN (1-1.5%)
α – labor share in GDP	Normal DISTN (Mean 6% Std Dev- 3.35%)
$(\dot{L}/L)$ – rate of growth in employment	Normal DISTN (Mean 1% Std Dev- .7 %)
$(\dot{K}/K)$ – rate of growth of capital	Uniform DISTN (8-9%)
γ – proportion of GDP spent on defense	Uniform DISTN (2-3%)

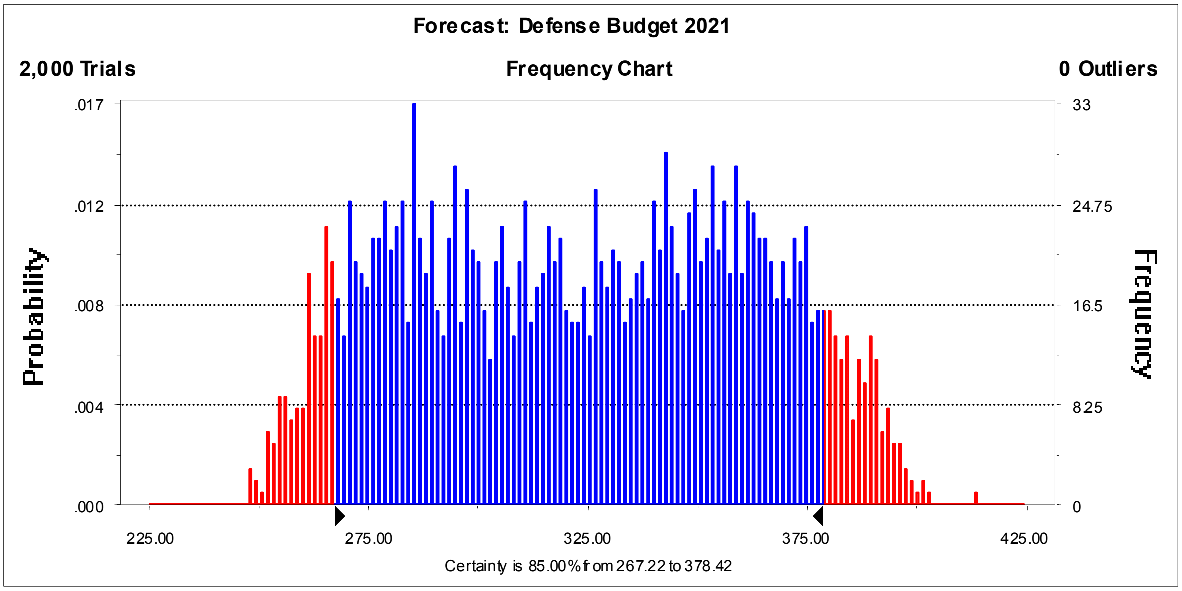
The model was run until 2021, which was chosen as the forecast year. Results are presented in detail in Appendix A. The 2021 GDP mean forecast result from was \$12.94 trillion in purchasing power parity (PPP)[3]. The chart below is the Crystal Ball output for a GDP run with 2000 trials. An 85% confidence level is displayed which ranges from \$12.5 to \$13.4 trillion.



A snapshot of the range of GDP growth rates of the simulation show that they vary between 3.68% and 6.91% but are centered near the 5.2% area.

The simulation yielded the following results for total defense budget. The distribution of outcomes appears less normal than that of GDP and has a mean value of \$323.80 billion. The outer confidence limits are \$267.2 to \$378.4, which is a fairly wide spread, possibly as an artifact of the assumptions in the simulation.

[3]Note: for the remainder of this chapter all forecasts are in purchasing power parity (PPP) to US dollars.



While the likelihood of all of the model's parametric values remaining within the historical norms for the next 20 years might be fairly remote, this case provides baseline information to planners. One insight from this analysis might indicate when (given this scenario) China's GDP and military spending is comparable to that of the United States or other competitor nations. The uncertainty statement could then be assessed. This sort of analysis would also provide insight into the possibility of a future China becoming a peer competitor. This could conceivably lead decision makers to explore alternative courses of action such as diplomacy or alliance. Of course the same analysis should also be applied to other nations in the region.

E. SUSPENDED GROWTH SCENARIO

This scenario reflects a major change occurring at about 2010. Up to this point the model follows the continued growth scenario. In fact, the same parameter values and their respective distributions were used for this period. In the year 2010 a combination of negative developments severely disrupts China's economic progress.

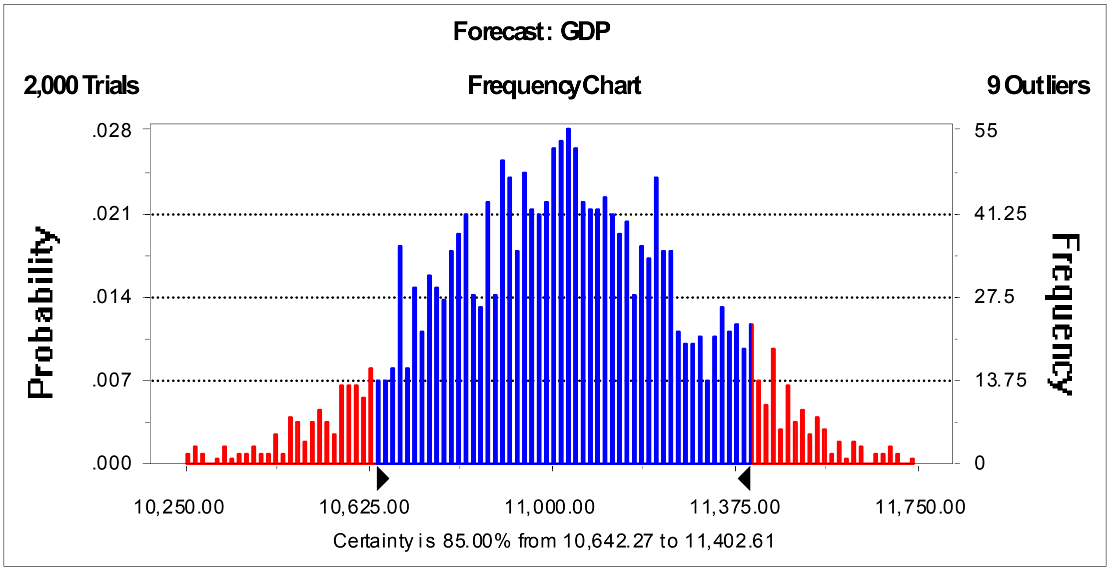
Specifically, a major rift develops along demographic lines. Spurred by the rapid proliferation of the Internet (to the chagrin of the established regime). Chinese interest groups have begun to organize. These groups have differing objectives and opinions about the direction of their nation, but are united in distain for the repressive nature of the government. One such group is the Falun Gong movement, which had been brutally repressed for years. Despite this resistance the group was able to recruit new members and generate a resistance network on the Internet. Another is an increasingly militant movement of young, educated Chinese who are disenchanted with the stagnant nature of the communist party. Having been witness to the huge gains in prosperity and lifestyle in other Asian and Western Nations, they demand the opportunities. Realizing the effectiveness of the web for mobilization purposes, the Chinese government has cracked down, establishing a China-only intranet. All web sites on this domain are thoroughly reviewed for political congruity and moral standards. Outraged by this affront to their new found freedoms, younger Chinese wage a clandestine battle by word of mouth and secret channels of the net such as steganography (using images or video to hide text messages that can only be decrypted with a special key) to organize a resistance. The first manifestation of the covert movement is a massive under reporting of income. This is reflected in the model by percentage of GDP spent on defense since much of this money, normally due to the central government stays in the hands of the earners.

Additionally, there are massive demonstrations throughout the nation. The communist regime's first reaction was to quash them in the same manner as Tianamin Square in 1989. The PRC's position in the World Trade Organization is threatened as several members including the US decry Chinese human rights abuses. Instability caused by threats of foreign trade disruption has an adverse effect on total factor productivity growth labor and capital factors. These problems cause the economy to stumble significantly for a 10-year period until 2021.

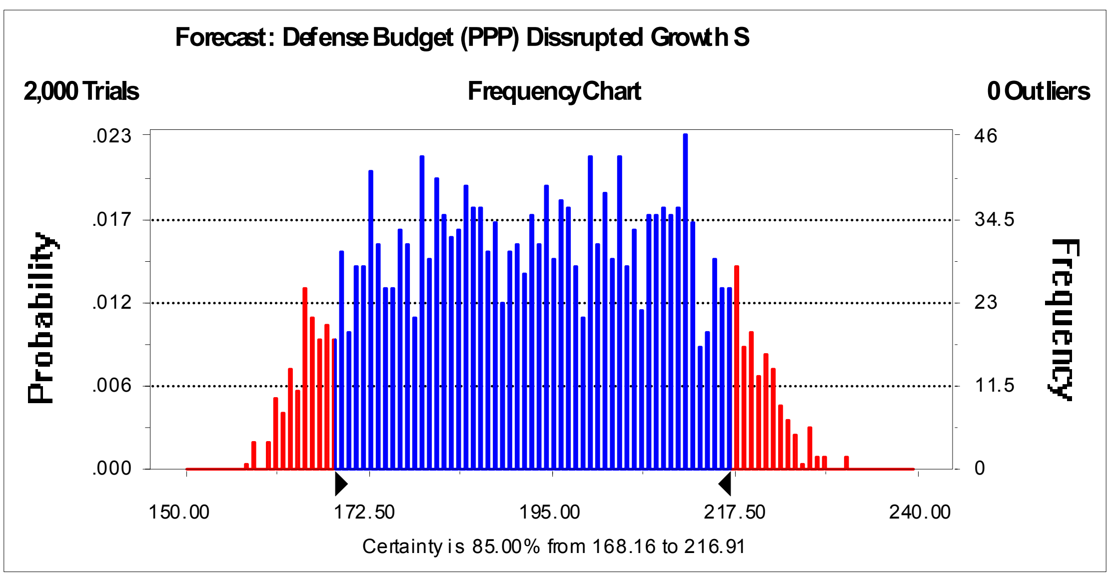
The following parameters were used in the model to represent the scenario:

τ – total factor productivity growth	2001-2009: Uniform DISTN (1-1.5%) 2010-2021: Uniform DISTN (.8-1.1%)
α – labor share in GDP	2001-2021: Normal DISTN (Mean .6 Std Dev- 3.35)
$(L^{\cdot}/L)$ – rate of growth of employment	2001-2009: Normal DISTN (Mean 1% Std Dev- .7 %) 2010-2021: Normal DISTN (Mean .8% Std Dev-.5 %)
$(K^{\cdot}/K)$ – rate of growth of capital	2001-2009: Uniform DISTN (8-9%) 2010-2021: Uniform DISTN (4-8%)
γ – proportion of GDP spent on defense	2001-2009: Uniform DISTN (2-3%) 2010-2021: Uniform DISTN (1.5-2%)

The resulting frequency chart for GDP in the forecast year of 2021 is presented below:



The GDP is centered at $11.02 trillion and the 85% confidence limits hold the figure in the range of $10.6 to $11.4 trillion range. Simulation results for defense budget are presented below:



The mean is $193.02 billion with 85% from 168.2 to 216.9. A detailed report of these results is included in Appendix B.

Despite the assumptions about the parameters of the model being altered significantly downward, the economy still experiences fairly robust growth. The ranges of estimates provided by the model for GDP growth rate are between 2.9 to 4.6% (for the 85% confidence level). While this is significantly lower than the 8% rate of the year 2000 the fact that the economy is growing despite the events is a powerful statement about its underlying strength.

F. ACCELERATED GROWTH SCENARIO

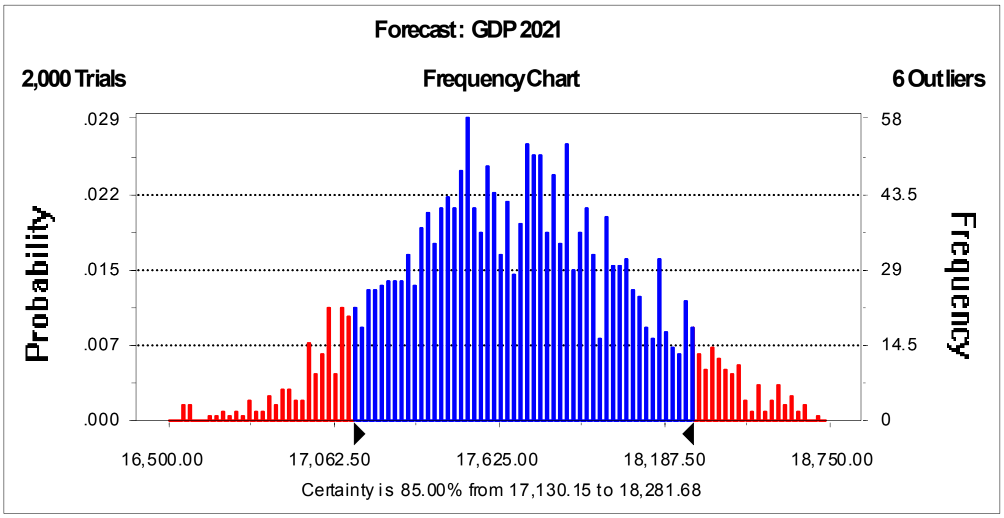
An accelerated growth case could be imagined where the inputs to the production function continue to improve. Schwartz and Ogilvy referred to this as the "Singapore x 70" scenario in their book entitled *China's Futures*. It describes a China that has become integrated, disciplined, efficient and benign, essentially Singapore many times bigger. (Ogilvy, Schwartz, 2000, p. 57)

The year 2008 is the year that things come together. Relations with the US have gradually warmed over the last seven years. Shared interest in minimizing violent Islamic movements and terrorism set the scene for a series of agreements on diplomatic and economic relations being extended between the two nations. Additionally, a new cultural movement is underway. Young Chinese people who have been raised with Internet images of Western and Asian nation's prosperity begin to come to power in industry and government. The communist zeal is waning, as freedom and opportunity become the watchwords of the new generation, many of whom have been educated in abroad.

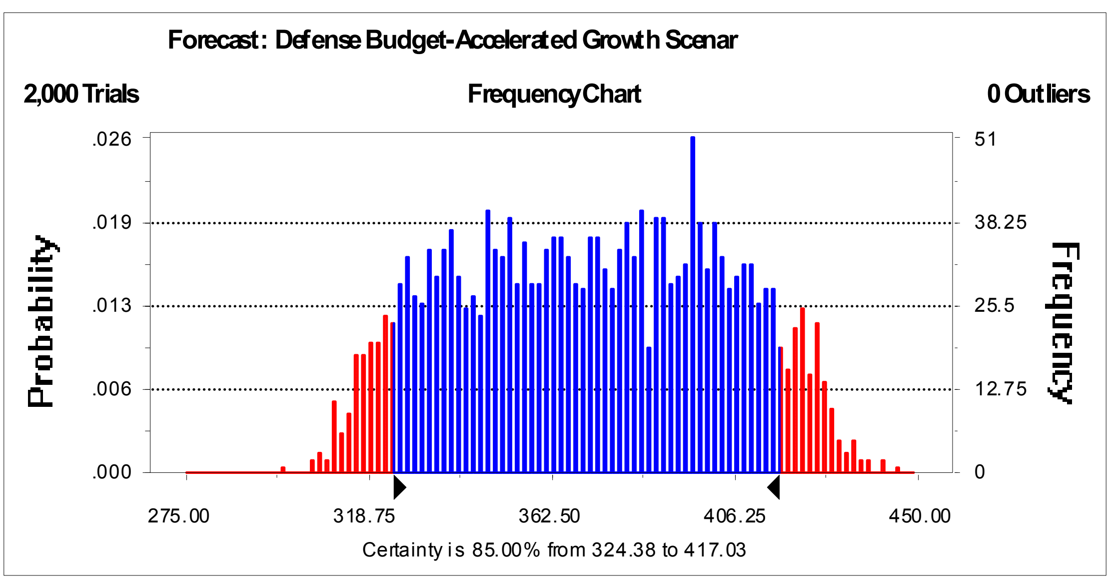
After acceptance into the World Trade Organization in 2001, China has cultivated an extensive web of relationships with Western and Asian trade partners. In 2010, after considerably reducing barriers to doing business, China was invited to join the Association of South East Asian Nations (ASEAN) by the residing members. This renaissance in regional relations coincides with technological gains that serve to alleviate the energy supply problem and boost efficiency of labor and capital.

This case required more manipulation of the data between the years to accurately reflect the nature of the scenario. A detailed discussion of these data distributions is presented in Appendix C.

As presented in the following chart, the forecast GDP for in 2021 has the staggering mean of $17.68 trillion. The uncertainty of this forecast within an 85% confidence level is between $17.1 and $18.2 trillion.



The growth rates that are reached under these conditions at the end of the 20-year epoch are between 7.5% and 9% a year. The resulting defense budget forecasts range between $324.4 and $417.0 billion for the 85% confidence level and have a mean of $371.85 billion. A detailed presentation of the results of this scenario can be found in Appendix D.

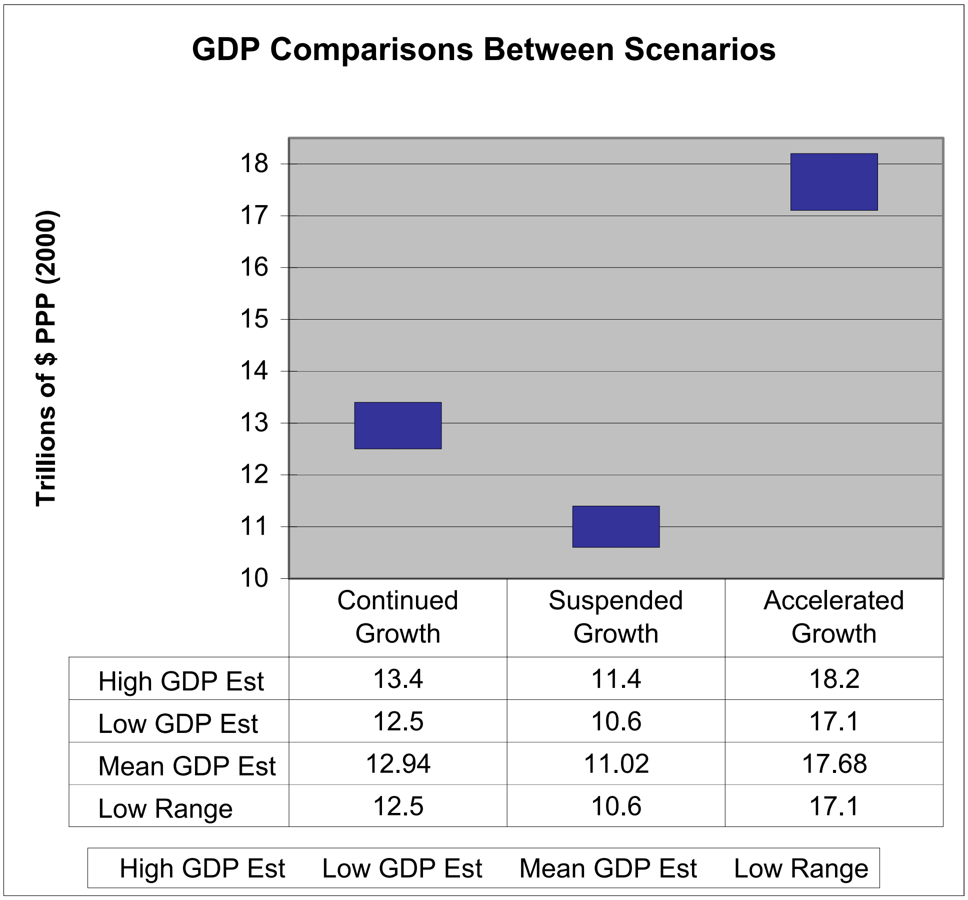


Evaluations of the results of this case present a compelling case for China to evolve to a true economic giant under very realistic assumptions. This analysis might provide incentive to the nation to reform their antiquated system to a more modern and efficient one. Their aims of being the rightful hegemon of the Pacific Rim would perhaps best be accomplished in this manner rather than the militaristic approach. In this scenario there was a lesser proportion of GDP spent on defense but the resulting budget was much higher. This balance between relative spending between defense and the private sector, highlight the opportunity costs faced with fielding a large military. This lesson was learned the hard way by the Soviet Union in the 1980's and is of key importance to leaders of all nations.

G. SUMMARY AND SCENARIO COMPARISON

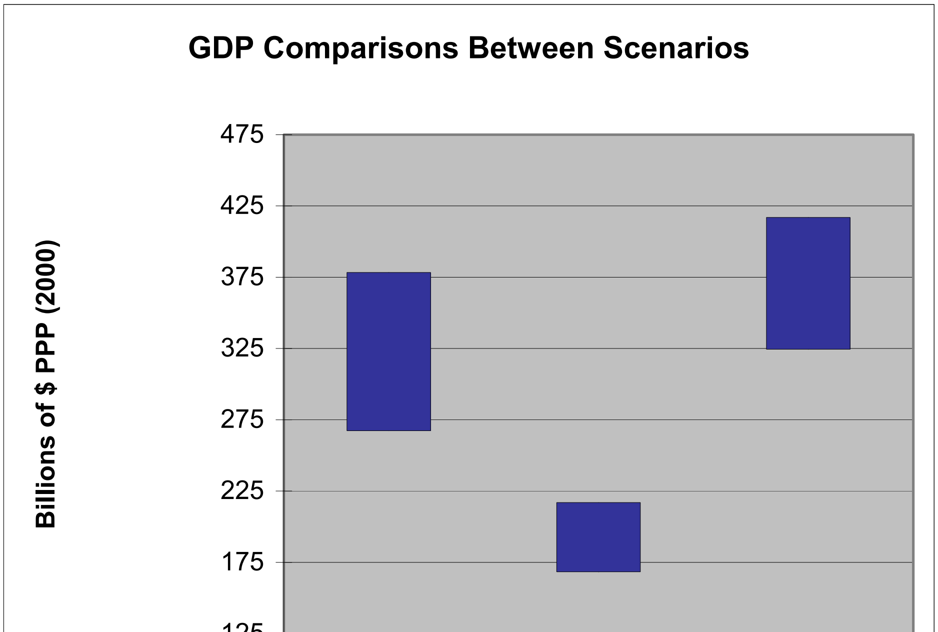
This chapter has illustrated the model that was developed in this thesis by applying it to the PRC. Three separate scenarios were chosen to represent a wide swath of realistic future possibilities. They all rely on actual driving issues and trends that could affect China's economic environment. These scenarios were represented in the theoretical mathematical constraints of the Cobb Douglas Production Function. Data and variance for the individual components of the model were chosen on the basis of historical data. This data was manipulated within realistic constraints to reflect the events that were unfolding in the scenarios.

After fully evaluating these scenarios and the uncertainties surrounding them, it is useful to compare their main tenants. The following chart highlights the differences in forecasted GDP in 2021 for the three cases.



	Continued Growth	Suspended Growth	Accelerated Growth
High GDP Est	13.4	11.4	18.2
Low GDP Est	12.5	10.6	17.1
Mean GDP Est	12.94	11.02	17.68
Low Range	12.5	10.6	17.1

From the chart it is apparent that there is no overlap at this point in the model. Certainly this would not be the case in earlier years before the cases clearly diverged. What is obvious however is the sheer difference in the numbers, which is literally trillions of dollars. This difference captures the first key layer of uncertainty that defense planners must contend with when looking out at a timeframe of this length. That is the uncertainty of possible outcomes. The range of the estimates presented in the chart represent the second layer of uncertainty. That is the potential variance in the model given the scenario. Similar observations can be seen in the following chart of forecasted defense budgets.



	Continued Growth	Suspended Growth	Accelerated Growth
High GDP Est	378.4	216.9	417
Low GDP Est	267.2	168.2	324.4
Mean GDP Est	323.8	193.02	371.85
	267.2	168.2	324.4

The variances between the scenarios and within are once again highlighted. These uncertainties are vital for the defense planner to fully comprehend. They translate into large ranges of possibilities for procurement of weapons systems or operational deployments. Through the development of these cases for the PRC the complexity of the task at hand for strategic planners is illustrated. Armed with this method, the full arrays of possibilities are highlighted for these decision makers giving them an improved mental model of the economic environment that they are working in.

VII. CONCLUSIONS AND RECOMMENDATIONS

A. SUMMARY

This study has evaluated a number of methods to aid the strategic planner in anticipating future developments. The economy was selected as a key issue. Means of effectively assessing the economic "terrain" and minimizing the risks of incorrect assumptions were identified. Traditional econometric modeling has imposed complex mathematical techniques on an essentially chaotic system with the aim of trying to predict the future. Despite their complexity and comprehensiveness, these models have never had much success. The main problem is that they usually rely on past information and performance to predict the future. Without the added depth of alternate scenarios, they provide a false sense of certainty about the future. Phenomena such as technological booms, catastrophic events and non-traditional business cycles can be explored using varying with scenarios but are not easily synthesized with mathematical functions.

The methodology presented in this paper combines econometric techniques with scenario building, risk analysis and Monte Carlo Simulation to provide a technique for defense planners that explicitly addresses two separate levels of uncertainty. First the uncertainty of what major developments will unfold, and second, how much variance is likely should those events unfold.

This technique, when used properly can provide value added in the form of insight and improved mental models of the world. Armed with an extensive set of insights and knowledge the decision maker can attack the arduous task of constructing an effective military. Although the focus of this study was on economics as a driving factor, the basic framework of the technique might be adapted to other key areas.

The benefits of this combined methodology might be best described in terms of an analogy from perspective of military pilots (author's occupation). Use of simulation for training purposes has become an effective part of training aviators throughout their career. Flight simulators allow scenarios such as severe emergencies, disrupted communications and poor weather to be played out without danger to the crew. The use of multiple problem-solving techniques within these simulations is required for successful completion. A thoughtful review of what actions were taken and their consequences helps provide the crews feedback. The aim of these exercises is to add to the experience and confidence of the crew. Basically they improve the mental models of the aircrew.

The analogy to the technique presented for defense planning is obvious. Though this methodology the key issues that drive the problem can be evaluated from their conceptual roots to future possible outcomes within a descriptive model. It is in many ways, a simulator for defense planners. Their future abilities to react to changes in the economic situation are improved in the same way pilot's abilities are enhance by encountering emergencies in the flight simulator.

B. INSIGHTS FROM THE PRC EXERCISE

While this study focused on the economy of the PRC independent of other nations, insights can be reaped from the process. First the sheer size and potential of a modern China is illustrated in all three scenarios. Even in the interrupted growth case the economy would grow at a substantial rate. The accelerated growth case further illustrates this potential power. The implications are obvious to the US. The PRC has real potential to be a peer competitor in the coming decades. Without substantial changes in the balance of power in the Pacific Rim, it is likely that the US position as a dominant regional force will diminish. With these insights in mind, planners should construct defense forces to anticipate this possibility.

C. SUGGESTIONS FOR FUTURE RESEARCH

While this study focused on the PRC to illustrate the proposed methods, it could obviously be applied to other nations. Future studies might utilize this technique to study a certain geographical area with of interdependent scenarios. One such area might be the Pacific Rim, since many believe that it will be a center for future growth as well as an area of competing interests and potential strife. An evaluation of Middle East nation's economic growth and military capability within the context of scenarios evaluating the effects of such as a gradually westernizing trends or a retreat to fundamentalism would be of value. Scenarios in the European theater would also be valuable for future research.

Within these "stories of the future," parameters and their respective statistical distributions can be adjusted as new trends emerge. While it is impossible to cover the entire gamut of potential real world developments, emerging trends and driving forces can be applied to this model to ascertain the effects on power. Additionally Bayesian posterior probability analysis could continuously refine and improve the models. As always, the additional insights to the decision maker are the value added of the model.

Additional layers of model complexity are another area where future research might be directed. The RAND study that was introduced in Chapter IV examined estimates of military capital based on depreciation and procurement estimates. The addition of this step to the model would provide a bottom line military force potential estimate. This data could be incorporated into net assessments of force-on-force conflict. From this knowledge, better decisions about resource allocation could be made. Also and examination of the empirical data and actual model performance in terms of variable sensitivity analysis could identify critical economic nodes for targeted public policies.

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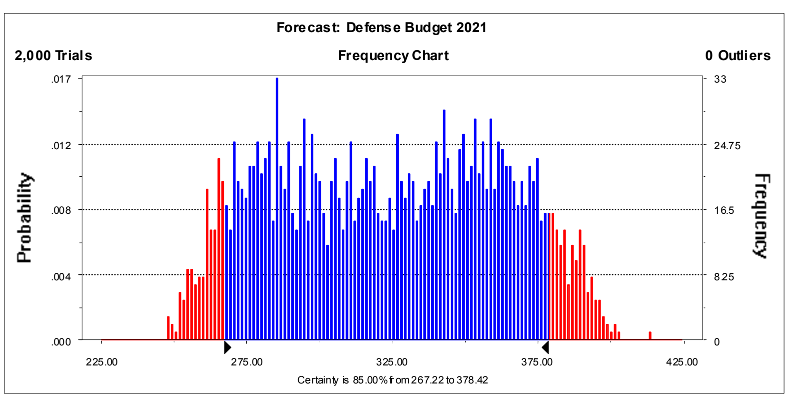
APPENDIX A. CONTINUED GROWTH SCENARIO REPORT

Continued Growth Scenario - Crystal Ball Report
Simulation started on 11/27/01 at 21:17:11
Simulation stopped on 11/27/01 at 21:20:53

Forecast: Defense Budget 2021 **Cell: V19**

Summary:
- Certainty Level is 85.00%
- Certainty Range is from 267.22 to 378.42
- Display Range is from 225.00 to 425.00
- Entire Range is from 248.09 to 413.38
- After 2,000 Trials, the Std. Error of the Mean is 0.86

Statistics:	Value
Trials	2000
Mean	323.81
Median	324.61
Mode	---
Standard Deviation	38.62
Variance	1,491.56
Skewness	0.00
Kurtosis	1.85
Coeff. of Variability	0.12
Range Minimum	248.09
Range Maximum	413.38
Range Width	165.29
Mean Std. Error	0.86



Forecast: Defense Budget 2021 (cont'd) **Cell: V19**

Percentiles:

Percentile	Value
0%	248.09
10%	271.44
20%	283.75
30%	296.28
40%	310.37
50%	324.61
60%	338.66
70%	350.83
80%	362.24
90%	375.17
100%	413.38

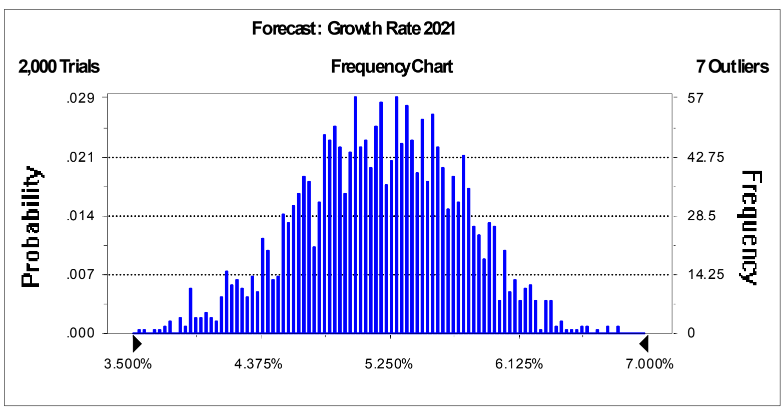
End of Forecast

Forecast: Growth Rate 2021 **Cell: V13**

Summary:

Display Range is from 3.500% to 7.000%
Entire Range is from 3.120% to 7.133%
After 2,000 Trials, the Std. Error of the Mean is 0.012%

Statistics:	Value
Trials	2000
Mean	5.185%
Median	5.198%
Mode	---
Standard Deviation	0.553%
Variance	0.003%
Skewness	-0.18
Kurtosis	3.07
Coeff. of Variability	0.11
Range Minimum	3.120%
Range Maximum	7.133%
Range Width	4.013%
Mean Std. Error	0.012%



Forecast: Growth Rate 2021 (cont'd) **Cell: V13**

Percentiles:

Percentile	Value
0%	3.120%
10%	4.475%
20%	4.716%
30%	4.894%
40%	5.052%
50%	5.198%
60%	5.347%
70%	5.493%
80%	5.662%
90%	5.870%
100%	7.133%

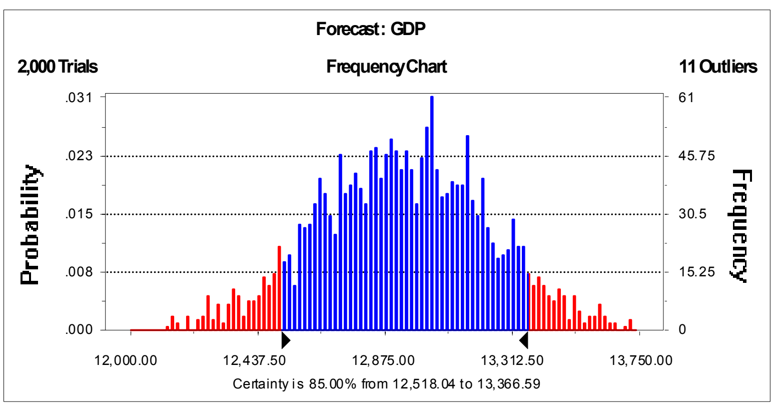
End of Forecast

Forecast: GDP **Cell: V15**

Summary:

Certainty Level is 85.00%
Certainty Range is from 12,518.04 to 13,366.59
Display Range is from 12,000.00 to 13,750.00
Entire Range is from 12,126.53 to 14,089.04
After 2,000 Trials, the Std. Error of the Mean is 6.65

Statistics:	Value
Trials	2000
Mean	12,943.17
Median	12,942.06
Mode	---
Standard Deviation	297.32
Variance	88,399.92
Skewness	0.08
Kurtosis	2.98
Coeff. of Variability	0.02
Range Minimum	12,126.53
Range Maximum	14,089.04
Range Width	1,962.51
Mean Std. Error	6.65



Forecast: GDP (cont'd) **Cell: V15**

Percentiles:

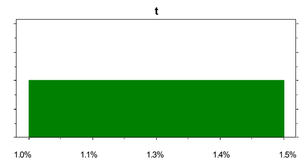
Percentile	Value
0%	12,126.53
10%	12,564.73
20%	12,682.25
30%	12,781.93
40%	12,863.89
50%	12,942.06
60%	13,023.40
70%	13,102.11
80%	13,189.67
90%	13,325.61
100%	14,089.04

End of Forecast

<u>**Assumptions**</u>

Assumption: t | **Cell: B7**

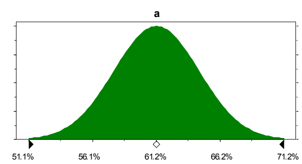
Uniform distribution with parameters:
Minimum 1.0%
Maximum 1.5%



Mean value in simulation was 1.2%

Assumption: a | **Cell: B9**

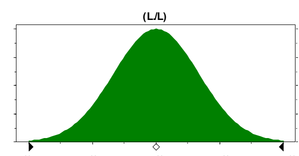
Normal distribution with parameters:
Mean 61.2%
Standard Dev. 3.4%



Selected range is from -Infinity to +Infinity
Mean value in simulation was 61.3%

Assumption: (L./L) | **Cell: B10**

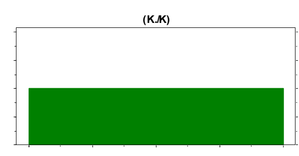
Normal distribution with parameters:
Mean 1.0%
Standard Dev. 0.7%



Selected range is from -Infinity to +Infinity
Mean value in simulation was 1.0%

Assumption: (K./K) | **Cell: B11**

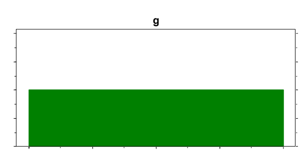
Uniform distribution with parameters:
Minimum 8.0%
Maximum 9.0%



Mean value in simulation was 8.5%

Assumption: g | **Cell: B17**

Uniform distribution with parameters:
Minimum 2.0%
Maximum 3.0%



Mean value in simulation was 2.5%

End of Assumptions

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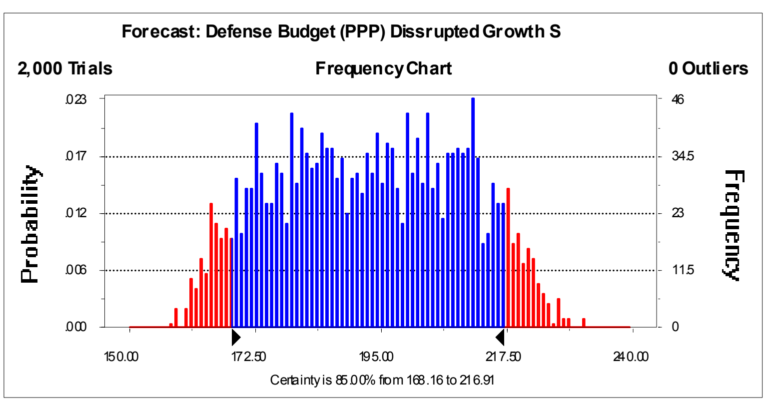
APPENDIX B. SUSPENDED GROWTH SCENARIO REPORT

Suspended Growth Scenario - Crystal Ball Report
Simulation started on 11/27/01 at 20:17:52
Simulation stopped on 11/27/01 at 20:21:18

Forecast: Defense Budget (PPP) Dissrupted Growth S **Cell: V19**

Summary:
Certainty Level is 85.00%
Certainty Range is from 168.16 to 216.91
Display Range is from 150.00 to 240.00
Entire Range is from 157.52 to 231.67
After 2,000 Trials, the Std. Error of the Mean is 0.37

Statistics:	Value
Trials	2000
Mean	193.02
Median	193.24
Mode	---
Standard Deviation	16.62
Variance	276.29
Skewness	-0.01
Kurtosis	1.99
Coeff. of Variability	0.09
Range Minimum	157.52
Range Maximum	231.67
Range Width	74.15
Mean Std. Error	0.37



Percentiles:

Percentile	Value
0%	157.52
10%	170.51
20%	176.72
30%	182.01
40%	187.24
50%	193.24
60%	198.64
70%	203.92
80%	209.62
90%	215.42
100%	231.67

Frequency Counts:

Frequency:

Group	Start Value	End Value	Prob.	Freq.
	-Infinity	150.00	0.000000	0
1	150.00	150.90	0.000000	0
2	150.90	151.80	0.000000	0
3	151.80	152.70	0.000000	0
4	152.70	153.60	0.000000	0
5	153.60	154.50	0.000000	0
6	154.50	155.40	0.000000	0
7	155.40	156.30	0.000000	0
8	156.30	157.20	0.000000	0
9	157.20	158.10	0.000500	1
10	158.10	159.00	0.002000	4
11	159.00	159.90	0.000000	0
12	159.90	160.80	0.002000	4
13	160.80	161.70	0.005000	10
14	161.70	162.60	0.004000	8
15	162.60	163.50	0.007000	14
16	163.50	164.40	0.005500	11
17	164.40	165.30	0.012500	25
18	165.30	166.20	0.010500	21
19	166.20	167.10	0.009000	18
20	167.10	168.00	0.010000	20
21	168.00	168.90	0.009000	18
22	168.90	169.80	0.015000	30
23	169.80	170.70	0.009500	19
24	170.70	171.60	0.014000	28

Forecast: Defense Budget (PPP) Dissrupted Growth S (cont'd) **Cell: V19**

Group	Start Value	End Value	Prob.	Freq.
25	171.60	172.50	0.014000	28
26	172.50	173.40	0.020500	41
27	173.40	174.30	0.015500	31
28	174.30	175.20	0.012500	25
29	175.20	176.10	0.012500	25
30	176.10	177.00	0.016500	33
31	177.00	177.90	0.015500	31
32	177.90	178.80	0.010500	21
33	178.80	179.70	0.021500	43
34	179.70	180.60	0.014500	29
35	180.60	181.50	0.020000	40
36	181.50	182.40	0.017500	35
37	182.40	183.30	0.016000	32
38	183.30	184.20	0.016500	33
39	184.20	185.10	0.019500	39
40	185.10	186.00	0.018000	36
41	186.00	186.90	0.018000	36
42	186.90	187.80	0.015000	30
43	187.80	188.70	0.017000	34
44	188.70	189.60	0.011500	23
45	189.60	190.50	0.015000	30
46	190.50	191.40	0.015500	31
47	191.40	192.30	0.013500	27
48	192.30	193.20	0.017500	35
49	193.20	194.10	0.015500	31
50	194.10	195.00	0.019500	39
51	195.00	195.90	0.014500	29
52	195.90	196.80	0.018500	37
53	196.80	197.70	0.018000	36
54	197.70	198.60	0.014000	28
55	198.60	199.50	0.010500	21
56	199.50	200.40	0.021500	43
57	200.40	201.30	0.015500	31
58	201.30	202.20	0.019000	38
59	202.20	203.10	0.014500	29
60	203.10	204.00	0.021500	43
61	204.00	204.90	0.014000	28
62	204.90	205.80	0.016500	33
63	205.80	206.70	0.011000	22
64	206.70	207.60	0.017500	35
65	207.60	208.50	0.017500	35
66	208.50	209.40	0.018000	36

Forecast: Defense Budget (PPP) Dissrupted Growth S (cont'd) **Cell: V19**

	Group	Start Value	End Value	Prob.	Freq.
	67	209.40	210.30	0.017500	35
	68	210.30	211.20	0.018000	36
	69	211.20	212.10	0.023000	46
	70	212.10	213.00	0.017000	34
	71	213.00	213.90	0.008500	17
	72	213.90	214.80	0.009500	19
	73	214.80	215.70	0.014500	29
	74	215.70	216.60	0.012500	25
	75	216.60	217.50	0.012500	25
	76	217.50	218.40	0.014000	28
	77	218.40	219.30	0.008500	17
	78	219.30	220.20	0.009500	19
	79	220.20	221.10	0.006500	13
	80	221.10	222.00	0.008000	16
	81	222.00	222.90	0.007000	14
	82	222.90	223.80	0.004500	9
	83	223.80	224.70	0.003500	7
	84	224.70	225.60	0.002500	5
	85	225.60	226.50	0.000500	1
	86	226.50	227.40	0.003000	6
	87	227.40	228.30	0.001000	2
	88	228.30	229.20	0.001000	2
	89	229.20	230.10	0.000000	0
	90	230.10	231.00	0.000000	0
	91	231.00	231.90	0.001000	2
	92	231.90	232.80	0.000000	0
	93	232.80	233.70	0.000000	0
	94	233.70	234.60	0.000000	0
	95	234.60	235.50	0.000000	0
	96	235.50	236.40	0.000000	0
	97	236.40	237.30	0.000000	0
	98	237.30	238.20	0.000000	0
	99	238.20	239.10	0.000000	0
	100	239.10	240.00	0.000000	0
		240.00	+Infinity	0.000000	0
Total:				1.000000	2000

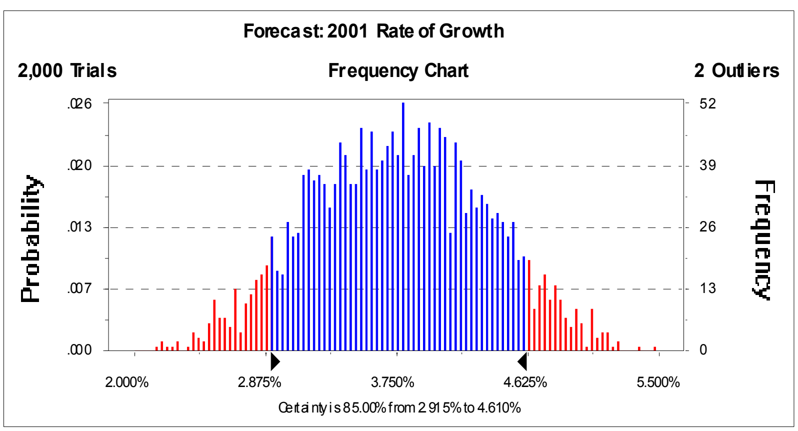
Cumulative:

Group	Start Value	End Value	Prob.	Freq.
	-Infinity	150.00	0.000000	0
1	150.00	150.90	0.000000	0
2	150.90	151.80	0.000000	0

Forecast: 2001 Rate of Growth **Cell: V13**

Summary:
- Certainty Level is 85.00%
- Certainty Range is from 2.915% to 4.610%
- Display Range is from 2.000% to 5.500%
- Entire Range is from 2.158% to 5.530%
- After 2,000 Trials, the Std. Error of the Mean is 0.013%

Statistics:	Value
Trials	2000
Mean	3.771%
Median	3.774%
Mode	---
Standard Deviation	0.587%
Variance	0.003%
Skewness	0.03
Kurtosis	2.57
Coeff. of Variability	0.16
Range Minimum	2.158%
Range Maximum	5.530%
Range Width	3.372%
Mean Std. Error	0.013%



Forecast: 2001 Rate of Growth (cont'd) **Cell: V13**

Percentiles:

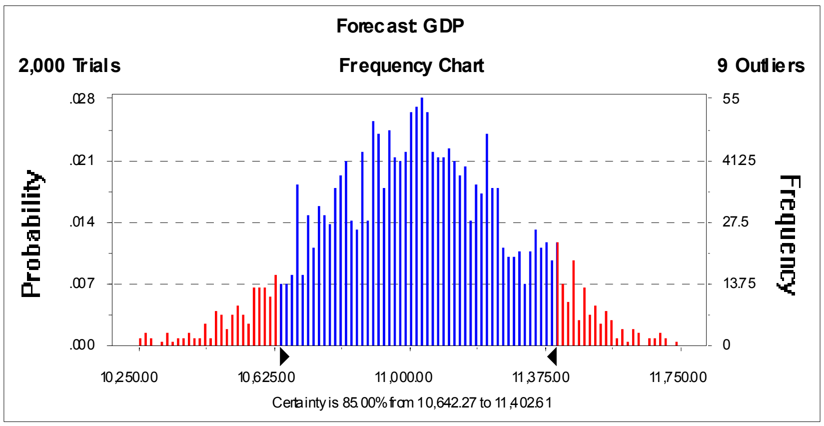
Percentile	Value
0%	2.158%
10%	3.016%
20%	3.238%
30%	3.431%
40%	3.597%
50%	3.774%
60%	3.934%
70%	4.091%
80%	4.292%
90%	4.541%
100%	5.530%

Forecast: GDP **Cell: V15**

Summary:

Certainty Level is 85.00%
Certainty Range is from 10,642.27 to 11,402.61
Display Range is from 10,250.00 to 11,750.00
Entire Range is from 10,069.19 to 11,840.23
After 2,000 Trials, the Std. Error of the Mean is 5.90

Statistics:	Value
Trials	2000
Mean	11,019.76
Median	11,020.64
Mode	---
Standard Deviation	263.65
Variance	69,509.31
Skewness	-0.04
Kurtosis	3.04
Coeff. of Variability	0.02
Range Minimum	10,069.19
Range Maximum	11,840.23
Range Width	1,771.04
Mean Std. Error	5.90



Forecast: GDP (cont'd) **Cell: V15**

Percentiles:

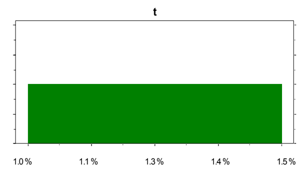
Percentile	Value
0%	10,069.19
10%	10,688.53
20%	10,796.84
30%	10,883.66
40%	10,955.25
50%	11,020.64
60%	11,081.70
70%	11,155.34
80%	11,236.90
90%	11,367.34
100%	11,840.23

Assumptions

Assumption: t **Cell: B7**

Uniform distribution with parameters:

Minimum	1.0%
Maximum	1.5%

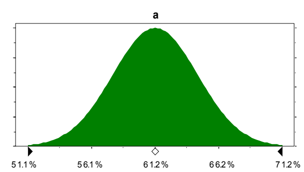


Mean value in simulation was 1.2%

Assumption: a **Cell: B9**

Normal distribution with parameters:

Mean	61.2%
Standard Dev.	3.4%

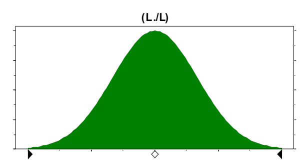


Selected range is from -Infinity to +Infinity
Mean value in simulation was 61.3%

Assumption: (L./L) **Cell: B10**

Normal distribution with parameters:

Mean	1.0%
Standard Dev.	0.7%

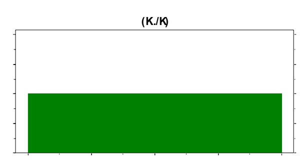


Selected range is from -Infinity to +Infinity
Mean value in simulation was 1.0%

Assumption: (K./K) **Cell: B11**

Uniform distribution with parameters:

Minimum	8.0%
Maximum	9.0%

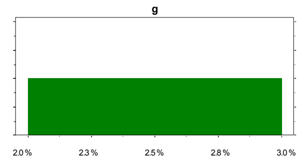


Mean value in simulation was 8.5%

Assumption: g **Cell: B17**

Uniform distribution with parameters:

Minimum	2.0%
Maximum	3.0%

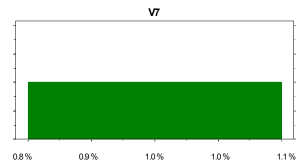


Mean value in simulation was 2.5%

Assumption: V7 **Cell: V7**

Uniform distribution with parameters:

Minimum	0.8%
Maximum	1.1%

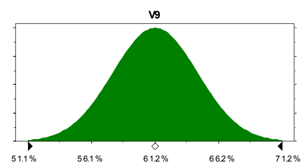


Mean value in simulation was 0.9%

Assumption: V9 **Cell: V9**

Normal distribution with parameters:

Mean	61.2%
Standard Dev.	3.4%

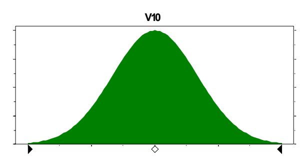


Selected range is from -Infinity to +Infinity
Mean value in simulation was 61.0%

Assumption: V10 **Cell: V10**

Normal distribution with parameters:

Mean	0.8%
Standard Dev.	0.5%

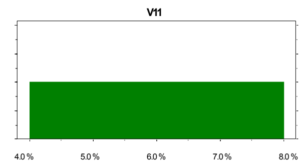


Selected range is from -Infinity to +Infinity
Mean value in simulation was 0.8%

Assumption: V11 **Cell: V11**

Uniform distribution with parameters:

Minimum	4.0%
Maximum	8.0%

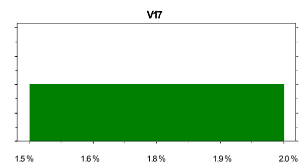


Mean value in simulation was 6.0%

Assumption: V17 **Cell: V17**

Uniform distribution with parameters:

Minimum	1.5%
Maximum	2.0%



Mean value in simulation was 1.8%

End of Assumptions

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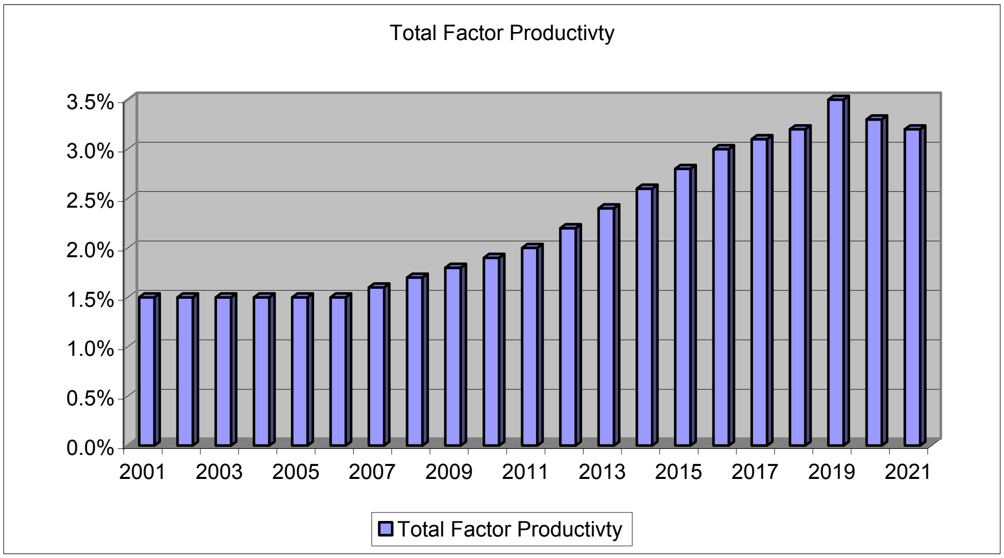
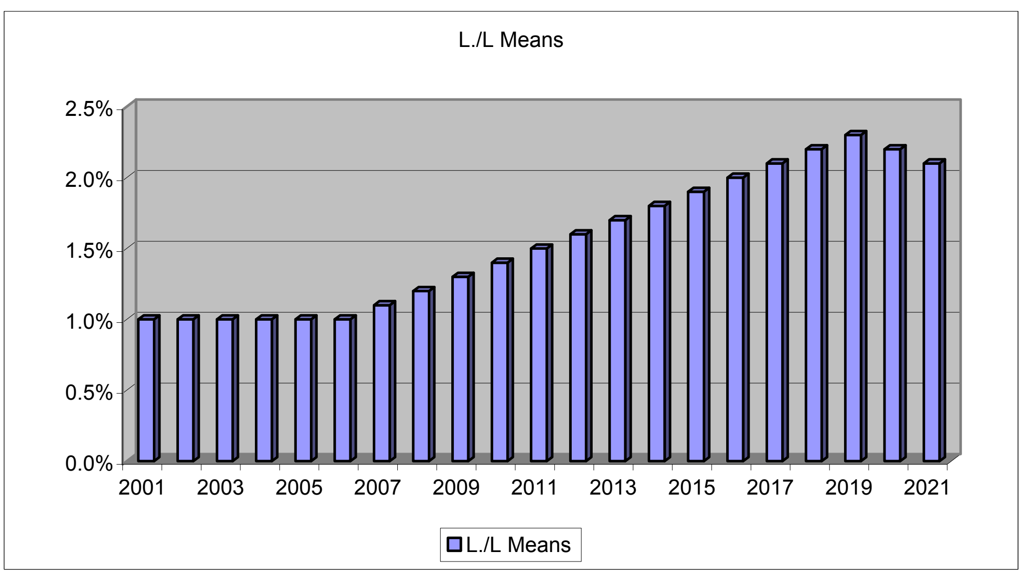
APPENDIX C. ACCELERATED GROWTH SCENARIO DATA

In order to represent the importance of the technological growth in this scenario, discrete values of total factor productivity (τ) were chosen for this model. Their value throughout the epic being studied is summarized in the following chart.



A normal distribution with a Mean of 60% and a standard deviation of 3.35% was used for labor share in GDP. The rate of growth of employment (L./L) was modeled with normal distributions with means summarized in the following chart. (Standard deviation was .6 for all years.)



Rate of growth of capital (K./K) was kept at the same level of prior simulations until 2009 where it was shifted slightly upwards to a uniform distribution ranging between 9 and 10%. This change reflects the increased willingness of the international community to invest in the nation as it begins to open up. Finally, the proportion of GDP spent on defense (γ) was represented with uniform distributions of 2-3% for the period of 2001-2007. As a result of the growing GDP and increased harmonious relationships in the hemisphere, this figure was adjusted to a uniform distribution between 1.8-2.4%.

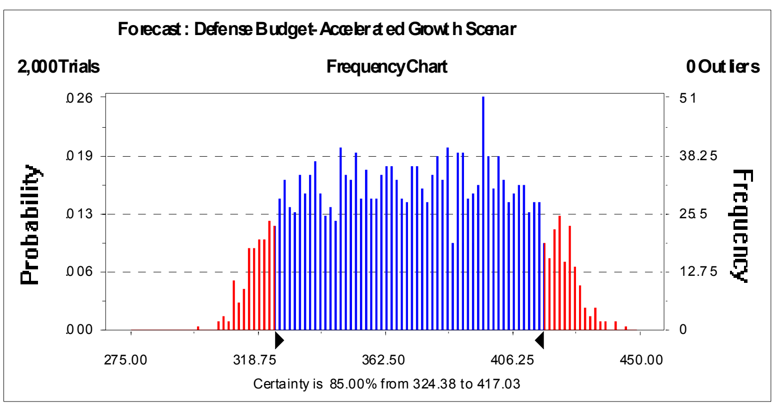
APPENDIX D. ACCELERATED GROWTH SCENARIO REPORT

Accerated Growth Scenario - Crystal Ball Report
Simulation started on 11/29/01 at 22:25:48
Simulation stopped on 11/29/01 at 22:28:44

Forecast: Defense Budget-Accelerated Growth Scenar **Cell: V19**

Summary:
- Certainty Level is 85.00%
- Certainty Range is from 324.38 to 417.03
- Display Range is from 275.00 to 450.00
- Entire Range is from 299.22 to 445.45
- After 2,000 Trials, the Std. Error of the Mean is 0.71

Statistics:	Value
Trials	2000
Mean	371.85
Median	372.50
Mode	---
Standard Deviation	31.85
Variance	1,014.45
Skewness	-0.01
Kurtosis	1.97
Coeff. of Variability	0.09
Range Minimum	299.22
Range Maximum	445.45
Range Width	146.23
Mean Std. Error	0.71



Forecast: Defense Budget-Accelerated Growth Scenar (cont'd) **Cell: V19**

Percentiles:

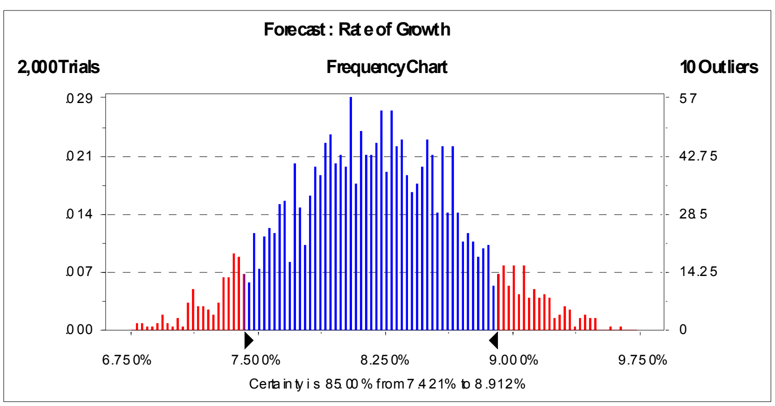
Percentile	Value
0%	299.22
10%	328.30
20%	339.38
30%	350.91
40%	361.66
50%	372.50
60%	382.81
70%	393.12
80%	402.81
90%	414.70
100%	445.45

End of Forecast

Forecast: Rate of Growth **Cell: V13**

Summary:
- Certainty Level is 85.00%
- Certainty Range is from 7.421% to 8.912%
- Display Range is from 6.750% to 9.750%
- Entire Range is from 6.287% to 9.827%
- After 2,000 Trials, the Std. Error of the Mean is 0.011%

Statistics:	Value
Trials	2000
Mean	8.183%
Median	8.189%
Mode	---
Standard Deviation	0.512%
Variance	0.003%
Skewness	-0.07
Kurtosis	2.99
Coeff. of Variability	0.06
Range Minimum	6.287%
Range Maximum	9.827%
Range Width	3.539%
Mean Std. Error	0.011%



Forecast: Rate of Growth (cont'd) **Cell: V13**

Percentiles:

Percentile	Value
0%	6.287%
10%	7.523%
20%	7.745%
30%	7.919%
40%	8.055%
50%	8.189%
60%	8.313%
70%	8.466%
80%	8.613%
90%	8.838%
100%	9.827%

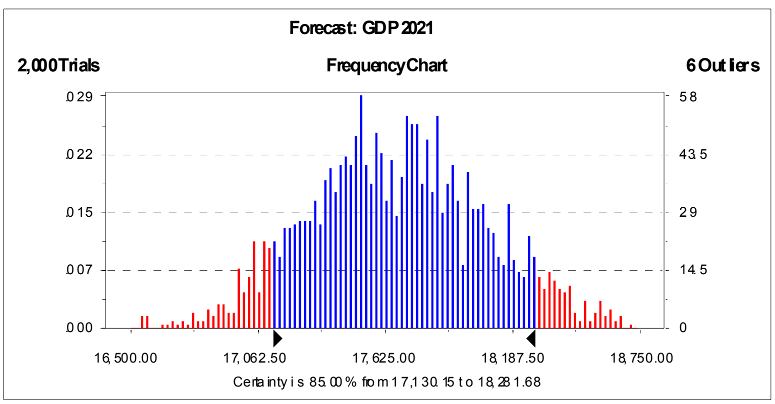
End of Forecast

Forecast: GDP 2021 **Cell: V15**

Summary:

Certainty Level is 85.00%
Certainty Range is from 17,130.15 to 18,281.68
Display Range is from 16,500.00 to 18,750.00
Entire Range is from 16,297.39 to 18,849.54
After 2,000 Trials, the Std. Error of the Mean is 8.80

Statistics:	Value
Trials	2000
Mean	17,675.28
Median	17,666.64
Mode	---
Standard Deviation	393.68
Variance	154,987.07
Skewness	0.04
Kurtosis	2.82
Coeff. of Variability	0.02
Range Minimum	16,297.39
Range Maximum	18,849.54
Range Width	2,552.15
Mean Std. Error	8.80



Forecast: GDP 2021 (cont'd) **Cell: V15**

Percentiles:

Percentile	Value
0%	16,297.39
10%	17,168.54
20%	17,339.82
30%	17,461.62
40%	17,557.35
50%	17,666.64
60%	17,771.73
70%	17,876.68
80%	18,017.07
90%	18,193.04
100%	18,849.54

End of Forecast

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